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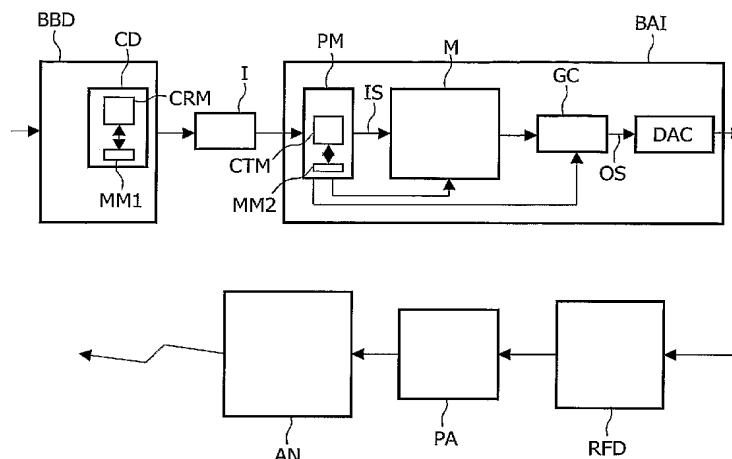
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(54) Title: ENHANCED BIT MAPPING FOR DIGITAL INTERFACE OF A WIRELESS COMMUNICATION EQUIPMENT IN MULTI-TIME SLOT AND MULTI-MODE OPERATION



(57) Abstract: A control device (CD) is dedicated to the control of the transmission of coded values onto a digital interface (I) connecting a baseband device (BBD) and a baseband interface device (BAI), comprising at least a modulator (M) feeding a gain controller (GC), of a wireless communication equipment. The control device (CD) comprises a storing means (MM1) for storing a coding table establishing a correspondence between symbols for the baseband interface device (BAI) and coding values to transmit to this radiofrequency device through the digital interface (I). The coding table comprises a first group of symbols comprising data words for feeding the modulator (M) and a second group of symbols comprising command words for controlling the operation of the modulator (M) and/or the gain controller (GC). The control device (CD) also comprises a control means (CRM) arranged, when it receives a symbol from the baseband device (BBD), to determine in the storing means (MM1) the coded value corresponding to this symbol in order it could be transmitted to the baseband interface device (BAI) through the digital interface (I).



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ENHANCED BIT MAPPING FOR DIGITAL INTERFACE OF A WIRELESS
COMMUNICATION EQUIPMENT IN MULTI-TIME SLOT AND MULTI-MODE
OPERATION

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The present invention relates to the digital baseband transmission path of the wireless communication equipments, and more precisely to the control of the modulator and/or the gain controller of such equipments, through a digital interface.

10 In certain communication networks, such as GSM (Global System for Mobile communications), it has been proposed to enhance the data rate through new standards, such as the so-called EGPRS standard (Enhanced General Packet Radio Service). For instance the EGPRS standard has introduced in the GSM network a new modulation scheme, named 8PSK (8 Phase Shift Keying), to improve the data rate previously offered by the GMSK (Gaussian Minimum Shift Keying) modulation scheme.

15 For flexibility purpose of data transmission, the EGPRS standard defines a multi-time slot (or multislot) and multi-mode operation requiring that more than one time slot out of the eight time slots dividing a GSM frame could be used for data transmission with GMSK or 8PSK modulation. So, the EGPRS wireless communication equipments must comprise a modulator able to switch easily from a GMSK modulation scheme to an 8PSK modulation
20 scheme and vice versa in consecutive time slots.

But, as it is known by one skilled in the art, GMSK is a constant envelope modulation scheme which allows the use of a saturated power amplification with high efficiency, while 8PSK is a modulation scheme which delivers a modulated carrier that varies not only in phase but also in amplitude and therefore can not allow the use of a saturated
25 power amplification but for instance a linear one.

So, in multislot operation the modulation scheme changes but also possibly the power amplification mode, which unfortunately introduces interferences between the adjacent channels associated to consecutive time slots.

30 In order to reduce these interferences it has been proposed to ramp down the transmit power by means of the gain controller of a power amplifier and to change the modulator and/or the power amplification mode during a guard period provided between the consecutive time slots. It is recalled that the guard period is a time interval dedicated to

control and/or switching operation without data transmission.

An alternative to this solution has been notably described in the patent document WO 2004/021659. It consists of a joint GMSK/8PSK I/Q modulator adapted to power ramping by means of I/Q signal shaping (where I and Q are respectively in-phase and quadrature components), without changing neither the power amplification mode nor the modulators. This is done by feeding with zeros the joint GMSK/8PSK I/Q modulator, thereby allowing control of the power of the I/Q signals.

If an external power control loop is used it is required that the modulator function be decoupled from the power control loop, or in other words that the ramping of the power amplifier be not determined by the modulator behaviour, but strictly by the power control loop. This stringent condition requires that the modulator output signal has an instantaneous transition between on/off states (data mode versus forced-zero mode) rather than a smooth one. Such transitions require that the modulation switching as well as the gain changes be timed accurately.

An industrial standard has been proposed to standardize the interfaces between the digital baseband processor (or device), the baseband interface (or BAI) and the radiofrequency (RF) device (which is connected to a power amplifier (or PA)).

It is recalled that, for the transmit direction, the digital baseband processor mainly comprises a digital signal processor (DSP) and a controller device (e.g., ARM) interfacing to the BAI, the baseband interface (or BAI) mainly comprises the modulator, a gain controller, a digital to analog converter (or DAC) and a postfilter interfacing to the radiofrequency (RF) device, and the RF device mainly comprises filters, gain stages and mixers. The digital baseband processor (or device), the baseband interface (or BAI), the radiofrequency (RF) device and the power amplifier (or PA) define what is named the transmission path of a wireless communication equipments.

The digital baseband processor, the BAI and the RF device may be defined on a same chip, or on separate chips, and any combination of two of these three devices may be also defined on a same chip. So, they may be connected one to the other in a "chip-to-chip connection mode" or in a "block-to-block connection mode" (when they are integrated on a same chip). But whatever the connection mode they need to be interfaced through a digital interface.

The industrial standard defines a digital interface, named "digital RF interface" and

capable of running a protocol named “digRF”, and a control device to facilitate the data transmission between the baseband device and the baseband interface (or BAI). This is done by means of a coding table stored in the control device and establishing a correspondence between symbols for the radiofrequency device and coding values to transmit to this
5 radiofrequency device through the digital interface.

For instance in the case of a GMSK/8PSK I/Q modulators the coding table comprises 16 symbols, two corresponding to data words for feeding the GMSK I/Q modulator, eight corresponding to data words for feeding the 8PSK I/Q modulator, and the last six being reserved for proprietary use.

10 Some more information about the digital interface, the digRF protocol and the environment thereof may be found at the Internet address “www.digrf.com”, for instance in the document “DigRF, Baseband / RF digital interface specification : Logical, Electrical and timing characteristics”, Version 1.12.

This industrial standard is not yet sufficient. So, the object of this invention is to
15 improve the situation.

For this purpose, it provides a control device, dedicated to the control of the transmission of coded values onto a digital interface connecting a baseband device and a baseband interface device (or BAI device) (comprising at least a modulator feeding a gain controller), of a wireless communication equipment, and comprising a storing means for
20 storing a coding table establishing a correspondence between symbols for the BAI device and coding values to transmit to the BAI device through the digital interface.

This control device is characterized in that its coding table comprises a first group of symbols comprising data words for feeding the modulator and a second group of symbols comprising command words for controlling the operation of the modulator and/or the gain
25 controller, but also in that it comprises a control means arranged, when it receives a symbol from the baseband device, to determine in the storing means the coded value corresponding to this symbol in order it could be transmitted to the radiofrequency device through the digital interface.

In other words the invention offers to use some of the symbols, stored in the coding
30 table, for feeding the modulator with data and the remaining symbols, also stored in the coding table, for the transmission of commands to the modulator and/or the gain controller, through the digital interface.

The control device according to the invention may include additional characteristics considered separately or combined, and notably :
35 - at least one of the symbols of the second group may be a command word for assigning a

chosen gain value to the gain controller,

- at least one of the symbols of the second group may be a command word for assigning a chosen working mode to a filter means and/or a modulation means of the modulator,
- at least one of the symbols of the second group may be a command word for assigning a chosen working mode to a filter means and/or a modulation means of the modulator and a chosen gain value to the gain controller,
- the working mode may be for instance an "initialization mode" for pre-loading the filter means with a chosen sequence of rotated valid symbols for an immediate up-ramping of the modulator, or a "reset mode" to force binary values of zero into the delay chain of the modulator's filter (to put all delays to zero, resulting in a sharp transition to zero output, i.e. an immediate down-ramping of the modulator), or else a "forced to zero mode" to force at least one binary value of zero into the modulator (which results in a smooth down ramping / up ramping at the input). In this case, the control device may be arranged to deliver a command word for assigning an initialization mode before transmission to the filter means of a last guard bit filling a guard interval, and/or to deliver a command word for assigning a reset mode just after the transmission of an active part of a data burst to the filter means and during the guard interval,
- when the modulator comprises a GMSK I/Q modulator and a 8PSK I/Q modulator, each coded value may be a four-bit word comprising three most significant bits (MSB) and a low significant bit (LSB) for differentiating the GMSK I/Q modulator from the 8PSK I/Q modulator. In this case, the first group may comprise at least eight symbols and the second group may comprise at least six symbols.

The invention also provides a baseband device, for a wireless communication equipment comprising a BAI device adapted to be connected to said baseband device through a digital interface, and comprising a control device such as the one above introduced.

The invention also provides a baseband interface device (or BAI device) for a wireless communication equipment comprising a baseband device such as the one above introduced and adapted to be connected to the BAI device through a digital interface. This BAI device comprises at least a modulator, a gain controller fed by the modulator, a storing means adapted to store a control table establishing a correspondence between coding values, transmitted by the digital interface, and symbols representing command words for controlling its operation and data words for feeding the modulator, and a control means connected to the

digital interface, the modulator and the gain controller, and arranged, when it receives a coding value from the digital interface, to determine in the storing means the word corresponding to the received coding value in order to transmit it to the modulator and/or the gain controller.

5 In alternative, the BAI device is dedicated to a wireless communication equipment comprising a baseband device connected to it, through a digital interface, and a control device such as the one above introduced.

It is important to notice that the baseband device, the BAI device and the RF device may be defined on a same chip, or on separate chips, and that any combination of two of these
10 three devices may be also defined on a same chip. But whatever the configuration these devices must use the above mentioned digital interface.

The invention also provides a wireless communication equipment comprising a baseband device, a digital interface, a control device such as the one above introduced, a BAI device such as the one above introduced, connected to the baseband device through the digital
15 interface, and a RF device connected to the BAI device.

In alternative, the wireless communication equipment may comprise a baseband device such as the one above introduced, a digital interface, a BAI device such as the one above introduced, connected to the baseband device through the digital interface, and a RF device connected to the BAI device.

20 Such equipments may be mobile phones, for instance.

Other features and advantages of the invention will become apparent on examining the detailed specifications hereafter and the appended drawings, wherein :

- figure 1 schematically illustrates an example of transmission path comprising a control device according to the invention,
- 25 - figure 2A schematically illustrates a simplified example of embodiment of a 8PSK I/Q modulator and a zeroth-order path of a linearized GMSK I/Q modulator belonging to a joint 8PSK/GMSK I/Q modulator of a communication device according to the invention,
- figure 2B schematically illustrates a simplified example of embodiment of the first-order (or quadratic) path of the linearized GMSK I/Q modulator belonging to a joint 8PSK/GMSK
30 I/Q modulator of a baseband interface device according to the invention, and
- figure 3 schematically illustrates a possible example of timing diagrams for the linearized GMSK I/Q modulator of figures 3A and 3B.

The appended drawings may not only serve to complete the invention, but also to contribute to its definition, if need be.

As above mentioned and as it is schematically illustrated in figure 1 a digital baseband transmission path of a wireless communication equipment comprises a digital baseband processor (or device) BBD, and a baseband interface device BAI, comprising at least a modulator M, a gain controller GC and a digital to analog converter DAC filter, connected to the digital baseband device BBD through a digital interface I. The digital baseband transmission path is connected to the radiofrequency (RF) device RFD which is itself connected to a power amplifier PA connected to an antenna AN. The digital baseband transmission path, the radiofrequency (RF) device RFD and the power amplifier PA constitute the transmission path.

It is important to notice that the gain stage of the digital baseband transmission path is usually distributed, one part comprising the gain controller GC being located inside the baseband interface device BAI (in a digital or analog form), and another part being located in the RF device RFD (in an analog form).

In the following description it will be considered that the digital interface I is of the type of the interface described in the above cited document "DigRF, Baseband / RF digital interface specification : Logical, Electrical and timing characteristics", Version 1.12. So, it will be considered in the following description, as an illustrating example, that the digital interface I is capable of running at least a part of the digRF protocol stack.

But the invention is not limited to this kind of digital interface.

Moreover, in the following description it will be considered (in a non limiting example of embodiment) that the baseband interface device BAI is a baseband and audio interface device.

Furthermore, in the following description it will be considered that the modulator M is a joint 8PSK/GMSK I/Q modulator installed in a wireless communication equipment, such as a GSM mobile phone with enhanced data rate according to the EGPRS (or EDGE) standard. In other words the modulator M is adapted to switch in multimode operation from a GMSK modulation scheme to an 8PSK modulation scheme and vice versa in consecutive time slots of a GSM frame.

But the invention is not limited to this kind of switching which requires a switching between the linear and non-linear modes of a power amplifier. Indeed this invention generally

applies to any switching schemes of modulators, and notably those based on Laurent's construction of digitally phase modulated signals by superposition of amplitude modulation pulses. Some more details about this Laurent's construction may be found in the document of P.A. Laurent "Exact and approximate construction of digital phase modulations by
5 superposition of amplitude modulated pulses (AMO)", IEEE Transactions on communications, Vol. 42, N°. 2/3/4, 1994.

Furthermore, the invention is not limited to modulators installed in mobile phone. The modulator according to the invention may be installed in any wireless communication equipment, and notably in laptop or PDA (Personal Digital Assistant) comprising a
10 communication device.

As it is known by one skilled in the art, the baseband device BBD of a mobile phone (for instance) mainly comprises a speech coder, a channel coder, an interleaver and a ciphering. This baseband device BBD is linked to the baseband and audio interface device BAI notably through the digital interface I (other connection means may be provided). The
15 baseband and audio interface device BAI comprises a processing module PM (comprising a burst formatter (or builder), a differential encoder for GMSK signals, and a control module CTM), the joint 8PSK/GMSK I/Q modulator M, the gain controller GC, and the digital to analog converter DAC.

As it is schematically illustrated in figure 1 the control module CTM may be external
20 to the modulator M, but it may also constitute a part of the joint 8PSK/GMSK modulator M.

The control module CTM, the joint 8PSK/GMSK I/Q modulator M, the gain controller GC and the digital to analog converter DAC are preferably integrated circuits.

As illustrated in figure 1 the baseband device BBD may comprise at least a part of a control device CD for controlling the transmission of coded values to the modulator M
25 through the digital interface I, which is capable of running the digRF protocol stack (in this non limiting example). This control device CD will be described below.

The modulator M is provided with digital input signals IS by the processing module PM and arranged, in the described example, to feed either an 8PSK I/Q modulator M1 or a linearized GMSK I/Q modulator M2 according to the type of the input signals IS to modulate.
30 In figure 2, M1 comprises MP1 and F0, M2 comprises M2₀ and M2₁, M2₀ comprises MP2₀ and F0 (shared with M1), and M2₁ comprises MP2₁ and F1.

As illustrated in figures 2A and 2B, the linearized GMSK I/Q modulator M2 preferably comprises a zero-th order modulation path M2₀ (MP2₀ and F0), also named linear path, and at least a first order modulation path M2₁ (MP2₁ and F1), also named quadratic
35 path, fed with the same input signals IS. It is important to notice that the linearized GMSK I/Q modulator M2 is more generally a n-th order GMSK I/Q modulator which comprises n + 1 modulation paths (n ≥ 0) fed with the same input signals IS. Therefore the modulator M may

comprise a GMSK I/Q modulator comprising more than two modulation paths.

The linear path comprises a modulation part $MP2_0$ feeding a filter part $F0$, also named $C0$ filter. The quadratic path comprises a modulation part $MP2_1$ feeding a filter part $F1$, also named $C1$ filter.

5 The 8PSK I/Q modulator $M1$ comprises a modulation part $MP1$ feeding the $C0$ filter $F0$ that it shares with the linear path of the linearized GMSK I/Q modulator $M2$.

The respective outputs of the $C0$ filter $F0$ and $C1$ filter $F1$ are connected to the inputs of a main combiner MC to feed it with modulated and filtered I/Q signals. The output of the main combiner MC is connected to the gain controller GC itself connected to the digital to
10 analog converter DAC to feed it with the modulated and filtered I/Q signals OS .

The 8PSK I/Q modulator $M1$ and the linearized GMSK I/Q modulator $M2$ each comprise a modulation section for generating modulated digital I/Q signals associated to time slots of GSM frames and a filter section for applying a chosen pulse shape defined by filter values to the digital I/Q signals in order to output modulated and filtered digital I/Q signals.

15 As is schematically illustrated in figure 2A the modulation part $MP1$ of the multislot 8PSK I/Q modulator $M1$ may comprise a serial to parallel converter SPC fed with serial data stream (or digital input signals) IS by the multiplexer MU of the modulator M . It is recalled that the speech signals (but it may be also pure data) may be quantized by the speech coder and then organized into data frames by the channel coder.

20 For instance the serial to parallel converter SPC is at least a three-bit serial to parallel converter that outputs three-bit parallel signals. Preferably it is a four-bit serial to parallel converter that outputs four-bit parallel signals where the LSB (Least Significant Bit) is used to distinguish between GMSK data and 8PSK data as well as between various active (or gain)/reset/preload modes.

25 The modulation part $MP1$ of the multislot 8PSK I/Q modulator $M1$ also comprises a Grey mapper GM fed with the three-bit parallel signals and arranged to map each bit triplet on one out of eight complex signals.

The modulation part $MP1$ of the multislot 8PSK I/Q modulator $M1$ also comprises a complex multiplier $CM0$ arranged to shape the I/Q signals outputted by the Grey mapper GM .
30 More precisely the complex multiplier $CM0$ is responsible for the mapping of the k -th symbols it receives onto the unit circle. The complex multiplier $CM0$ multiplies each received signal by a rotation signal equal to $\exp(jk3\pi/8)$ to introduce a rotation of $3k\pi/8$ radians.

The symbol mapping combines the signals outputted by the Grey mapper GM as well as the additional rotation symbol of the $\exp(j3\pi k/8)$ term. The Grey mapper GM can be seen
35 as a group of gates which translates the 3-bit symbols into the corresponding position on a unit circle according to a chosen rule. So the multiplier $CM0$ outputted rotated symbols which allow to avoid zero crossings in the RF envelope.

The modulation part MP1 of the multislot 8PSK I/Q modulator M1 also comprises a “shared” 3x1 multiplexer MX1 comprising a first input fed by the output of the complex multiplier CM0, a second input for zero setting, a third input fed by a complex multiplier CM1 of the modulation part MP2₀, and one output feeding with input samples an up-sampler US1 adapted to carry out an up-sampling aiming at inserting N-1 zeros after each input sample. For instance and as illustrated N=16.

The function of the multiplexer MX1 is to select between zeros during each guard period and the rotated 8PSK or GPSK symbols during the time slots (or active part of the bursts). Feeding the up-sampler US1 (and the following C0 filter F0) with zeros during the guard period enables a smooth step-on and step-off response of the C0 filter F0.

This up-sampler US1 feeds the shared filter part (or C0 filter) F0 with zeros or modulated digital 8PSK or GMSK I/Q signals through a multiplexer MX2₀.

The serial to parallel converter SPC, the Grey mapper GM, the multiplier CM0, the shared multiplexer MX1 and the shared up-sampler US1 constitute the modulation part MP1 of the multislot 8PSK I/Q modulator M1.

The C0 filter F0 is a pulse-shaping filter which has for instance 80 taps C0_i (i = 0 to n, where n = 79) and may be split into m sections F0_s (s = 1 to m), where m = 1 to 80, each having 80/m filter coefficients C0_i (for instance when m = 5 there are 5 sections each having 16 taps). This C0 filter F0 is used for 8PSK and shared with the zeroth-order part of the GMSK modulator. It is recalled that in GSM, the time-bandwidth product is BT = 0.3 and the Gaussian pulse is treated as limited to -2T...2T.

The C0 pulse-shaping filter F0 is preferably a low pass filter defining a finite impulse response (FIR) filter. Such a low pass filter is described in the document of P. Jung, “Laurent’s representation of binary digital continuous phase modulated signals with modulation index ½ revisited,” IEEE Trans. Comm., vol. 42, pp221-224, 1994.

Each part F0_i of the C0 pulse-shaping filter F0 applies a chosen pulse shape defined by filter values (or coefficients) C0_i(t) to the modulated digital I/Q signals it receives in order to output modulated and filtered digital I/Q signals. The signal serially travels through all F0_i.

Each filter coefficient C0_i of the C0 pulse-shaping filter F0 is fed with the same signals (possibly time delayed) through a multiplexer MX2_i. More precisely, the filter coefficient C0₀ is fed by the output of the multiplexer MX2₀, which also feeds one of the three inputs of the following multiplexer MX2₁ through a module T₁. The filter coefficient C0₁ is fed by the output of the multiplexer MX2₁, which also feeds one of the three inputs of the following multiplexer MX2₂ through a module T₂, and so on. And finally, the filter coefficient C0_n is fed by the output of the multiplexer MX2_n through a module T_n. Each module T_i (i = 1 to n) is arranged to introduce a chosen delay in time domain.

In the illustrated example, the C0 filter F0 also comprises n-1 combiners (or adders)

C1 to Cn for combining together the signals respectively outputted by each of its n filter coefficients C0_i. So the output of the last combiner (or adder) Cn of the C0 filter F0 is connected to one of the two inputs of the main combiner MC, whose output is connected to the gain controller GC, itself connected to the digital to analog converter DAC.

5 The zero-th order modulation path (MP2₀ and F0) of the multislot linearized GMSK I/Q modulator M2 comprises a mapper M0 arranged to map each received signals on one out of two complex signals.

 The zero-th order modulation path also comprises a complex multiplier CM1 arranged to shape the I/Q signals outputted by the mapper M0. The complex multiplier CM1 is responsible for the mapping of the symbols it receives onto the unit circle (the mapper M0 outputs the possible alphabet -1,1 and the complex multiplier CM1 maps the alphabet on the unit circle choosing one out of four possible positions). The complex multiplier CM1 multiplies each received signal by a rotation signal equal to $\exp(jk\pi/2)$ to introduce a rotation of $k\pi/2$ radians.

15 The multiplier CM1 is connected to the third input of the above mentioned shared 3x1 multiplexer MX1.

 The mapper M0, the multiplier CM1, the shared multiplexer MX1 and the shared up-sampler US1 constitute the modulation part MP2₀ of the multislot GMSK I/Q modulator M2.

20 The first order (or quadratic) modulation path (MP2₁ and F1) of the multislot linearized GMSK I/Q modulator M2 comprises a Finite State Machine FSM fed with the same digital GMSK signals than the mapper M0 of the zero-th order modulation path (MP2₀ and F0).

 The first order modulation path also comprises a mapper M1 arranged to map each signal coming from the Finite State Machine FSM on one out of two complex signals.

25 The first order modulation path also comprises a complex multiplier CM2 arranged to shape the I/Q signals outputted by the mapper M1. The complex multiplier CM2 multiplies each received signal by a rotation signal equal to $\exp(j(k-1)\pi/2)$ to introduce a rotation of $(k-1)\pi/2$ radians.

30 The first order modulation path also comprises a 2x1 multiplexer MX3 comprising one input fed by the output of the complex multiplier CM2, one input for zero setting and one output feeding with input samples an up-sampler US2 adapted to carry out an up-sampling aiming at inserting N-1 zeros after each input sample. For instance and as illustrated N=16.

 The function of the multiplexer MX3 is to select between zeros during each guard period and the rotated GMSK symbols (or bits) during the time slots (or active part of the bursts).

35 The Finite State Machine FSM, the mapper M1, the complex multiplier CM, the multiplexer MX3, and the up-sampler US2 defined together the modulation part MP2₁ of the

first order modulation path of the multislot linearized GMSK I/Q modulator M2.

The up-sampler US2 feeds the filter part (or C1 filter) F1 with zeros or modulated digital GMSK I/Q signals through a multiplexer MX4₀.

The C1 filter F1 is a pulse-shaping filter which has for instance 48 taps C1_j (j = 0 to k, where k = 47) and is split into p sections (F1_p, where p = 1 to 3 in this example), each having 16 filter coefficients C1_j. The filter lengths of both filters F0 and F1 have to be the same, namely 80 taps (so, k = n). However, the upper 32 taps of the C1 filter F1 are 0, so they do not have to be realized. It is important to notice that in order to insure a proper time alignment, the summation between the output of the C0 filter F0 and C1 filter F1 has to be done properly.

The C1 pulse-shaping filter F1 is preferably a low pass filter defining a finite impulse response (FIR) filter. Such a low pass filter is also described in the above mentioned document of P. Jung.

Each part F1_j of the C1 pulse-shaping filter F1 applies a chosen pulse shape defined by filter values (or coefficients) C1_j(t) to the modulated digital I/Q signals it receives in order to output modulated and filtered digital I/Q signals.

Each coefficient filter C1_j of the C1 pulse-shaping filter F1 is fed with the same signals (or a delayed version of it) through a multiplexer MX4_j. More precisely, the filter coefficient C1₀ is fed by the output of the multiplexer MX4₀, which also feeds one of the three inputs of the following multiplexer MX4₁ through a module T₁. The filter coefficient C1₁ is fed by the output of the multiplexer MX4₁, which also feeds one of the three inputs of the following multiplexer MX4₂ through a module T₂, and so on. And finally, the filter coefficient C1_k is fed by the output of the multiplexer MX4_k through a module T_k.

In the illustrated example, the C1 filter F1 also comprises k-1 combiners (or adders) C1 to C_k for combining together the signals respectively outputted by each of its k filter coefficients C1_j. So the output of the last combiner (or adder) C_k of the C1 filter F1 is connected to one of the two inputs of the main combiner MC, whose output is connected to the gain controller GC, itself connected to the digital to analog converter DAC.

In the illustrated example the joint modulator M also comprises initialization (or pre-load) means for loading the FIR filter states with a "dummy" sequence of rotated valid symbols during the guard period between two time slots, i.e. before the transmission of the active part of the burst ("initialization mode"), and/or just after the active part of a burst ("reset mode"). These rotated valid symbols are time-aligned with the consecutive guard bits and data bits which respectively fill the guard interval and the consecutive time slots that enclose it.

More precisely, the initialization operation aims at loading all the flip-flops in the C0 FIR filter F0 and C1 FIR filter F1 (modules T (for delay in time domain)) with valid symbols.

A valid symbol is any possible bit combination out of the GMSK alphabet and properly rotated (and delayed).

The rotation of the dummy sequence allows to switch between a dummy sequence and data bits without phase jumps. Effectively, the filter (F0, F1) having 80 taps, an input
 5 signal will have to travel first through the filter before being visible at the output. So, a valid dummy sequence of rotated valid symbols must be loaded into the FIR filters during the guard period when it is possible to transmit anything as long as it is compliant with the power-time template.

With this kind of initialization one can obtain a sharp transition from a very small
 10 amplitude (due to the absence of transmission during the guard period) to the required amplitude level.

The initialization (or pre-load) means may be divided in two parts : a first one MIa dedicated at least to the zeroth-order path (MP2₀ and F0) of the linearized GMSK I/Q modulator M2, and also possibly to the multislot 8PSK I/Q modulator M1 (as illustrated in
 15 figure 2A), and a second one MIb dedicated to the multislot first-order path (MP2₁ and F1) of the linearized GMSK I/Q modulator M2 (as illustrated in figure 2B).

In the example illustrated in figure 2A, the first part MIa of the initialization (or pre-load) means comprises a sub part MIO dedicated to the multislot 8PSK I/Q modulator M1 (and which is not mandatory when GMSK switching is only used) and a second part MI1
 20 dedicated to the zeroth-order path (MP2₀ and F0) of the linearized GMSK I/Q modulator M2.

The first sub part MIO comprises a serial to parallel converter SPC' fed with chosen sequence of initialization (or pre-load) bits PLS. As the serial to parallel converter SPC, this serial to parallel converter SPC' is for instance a three-bit serial to parallel converter that
 outputs three-bit parallel signals PLS.

25 The first sub part MIO also comprises a Grey mapper GM' fed with the three-bit parallel signals and arranged to map each bit triplet on one out of eight complex signals.

The first sub part MIO also comprises a complex multiplier CM0' arranged to shape the signals outputted by the Grey mapper GM'. The complex multiplier CM0' multiplies each received signal by a rotation signal equal to $\exp(jk3\pi/8)$ to introduce a rotation of $3k\pi/8$
 30 radians. So the multiplier CM0' outputs rotated symbols which allow to properly phase-align them with the input data when switching between preload, reset and active modes.

In an alternative it is possible to generate input sequences in which all the bits are equal to zero (0) or one (1). For this purpose it is possible to hardwire the complex multiplier CM0' input to minus one (-1) or one (1), thus omitting the serial to parallel converter SPC'
 35 and also the Grey mapper (or even the whole branch if the 8PSK initialization switching is not foreseen).

The second sub part MI1 comprises a mapper M0' fed with a chosen sequence of

initialization (or pre-load) bits PLS', and arranged to map each bit on one out of two complex signals as the mapper M0.

The second sub part MI1 also comprises a complex multiplier CM1' arranged to shape the signals outputted by the mapper M0'. The complex multiplier CM1' multiplies each received signal by a rotation signal equal to $\exp(jk\pi/2)$ to introduce a rotation of $k\pi/2$ radians. So the multiplier CM1' outputs rotated symbols which allow to properly phase-align them with the input data when switching between preload, reset and active modes.

In an alternative it is possible to generate input sequences in which all the bits are equal to zero (0) or one (1). For this purpose it is possible to hardwire the complex multiplier CM1' input to minus one (-1) or one (1), thus omitting the mapper M0'.

The first part MIa of the initialization means also comprises a shared 2x1 multiplexer MX0 comprising a first input fed by the output of the complex multiplier CM0', a second input fed by the complex multiplier CM1', and one output feeding with input samples an up-sampler US1' adapted to carry out an up-sampling aiming at inserting N-1 zeros after each input sample in order to output the chosen valid rotated bits for the initialization (or pre-loading) mode. In the illustrated example N=16.

The function of the multiplexer MX0 is to select between the rotated 8PSK and GPSK symbols during the pre-load or reset mode (when it is implemented, i.e. when the initialization of the 8PSK path is foreseen).

The output of the up-sampler US1' is connected to the first input of the multiplexer MX2₀ and to each first input of each other multiplexer MX2₁ to MX2_k respectively through modules T'₁ to T'_k (delay in time domain modules).

So the first input of each multiplexer MX2_i is fed with rotated signals for initialization (or pre-load) mode purpose, the second input of each multiplexer MX2_i is fed with rotated signals for active mode purpose, and the third input of each multiplexer MX2_i is fed with zeros sequence for a reset mode purpose.

The second part MIb of the initialization (or pre-load) means comprises a Finite State Machine FSM preferably fed with the same chosen sequence of initialization (or pre-load) bits PLS' than the mapper M0'.

The second part MIb also comprises a mapper M1' arranged to map each signal coming from the Finite State Machine FSM' on one out of two complex signals.

The second part MIb also comprises a complex multiplier CM2' arranged to shape the signals outputted by the mapper M1'. The complex multiplier CM2' multiplies each received signal by a rotation signal equal to $\exp(j(k-1)\pi/2)$ to introduce a rotation of $(k-1)\pi/2$ radians. So the multiplier CM2' outputs rotated symbols which allow to properly phase align them when switching between active, preload and reset modes.

The second part MIb also comprises an up-sampler US2' fed by the output of the

multiplier CM2' with the rotated symbol samples and adapted to carry out an up-sampling aiming at inserting N-1 zeros after each sample in order to output the chosen valid rotated bits for the initialization (or pre-loading) mode. In the illustrated example N=16.

The output of the up-sampler US2' is connected to the first input of the multiplexer MX4₀ and to each first input of each other multiplexer MX4₁ to MX4_k respectively through modules T'₁ to T'_k (delay in time domain modules).

So the first input of each multiplexer MX4_j is fed with rotated signals for initialization (or pre-load) mode purpose, the second input of each multiplexer MX4_j is fed with rotated signals for active mode purpose, and the third input of each multiplexer MX4_j is fed with zero sequence for a reset mode purpose.

In an alternative it is possible to generate input sequences in which all the bits are equal to zero (0) or one (1). For this purpose it is possible to hardwire the complex multiplier CM2' input to minus one (-1) or one (1), thus omitting the mapper M2' and the Finite State Machine FSM'.

One can notice that the complex multipliers CM1 and CM2 may comprise an additional input fed with a chosen constant value and respectively with the $\exp(jk\pi/2)$ and $\exp(j(k-1)\pi/2)$ terms, which results in the omission of the mappers MO and M1. This is possible because the initialization (or pre-loading) needs to be done only with valid and properly rotated symbols. For this purpose it is possible to hardwire the additional input to 1 (or -1) and still rotating by the CMi's results in a properly rotated dummy sequence which can be phase align with the active mode, i.e. switched without introducing phase jumps. In this case, it is also possible to omit the Finite State Machine FSM (which acts approximately as a modulo 2 adder) because it calculates the same output for every constant input.

The joint modulator M may also comprise reset means for loading the FIR filter states with an all zero sequence (coefficients C0(i) and C1(j)) just after the transmission of the active part of the burst and during the guard period. This chosen all zero sequence is provided to obtain a fast transition of the FIR filter states from the last valid symbol (with the transmitted amplitude) to the all zero state of the guard period which corresponds to a very small amplitude. The zero sequence travelling through the FIR filters appears as a smooth step-on/step-off at the filter's output.

Such an all zero sequence may be introduced through the third input of each multiplexer MX2_i or MX4_j, or else through the first input of each multiplexer MX2_i or MX4_j (dedicated to the pre-load (or initialization) signals) when it is generated by the initialization means (in this case the initialization means also acts as a reset means).

As mentioned above, in order the transitions between on/off states (data mode versus initialization modes) be instantaneous, the modulation switching as well as the gain changes must be timed accurately.

For this purpose the control device CD according to the invention comprises a dedicated memory MM1 in which is stored a coding table establishing a correspondence between symbols for the baseband and audio interface device BAI and coding values to transmit to the radiofrequency device RFD through the digital interface I.

5 More precisely, this coding table comprises a first group of symbols (for instance at least 8 and preferably 10 (8 for 8PSK and 2 for GMSK)) comprising data words for feeding the modulator M (M_1 , M_2 , and M_3) and a second group of symbols (for instance at least 6) comprising command words for controlling the operation of the modulator M and/or the gain controller GC.

10 Such a coding table allows to convert a symbol, generated in the baseband device BBD, into a specific coded value (or transmit symbol bits) adapted to be transmitted to the baseband and audio interface device BAI through the digital interface I.

When the baseband device BBD needs to transmit data or command(s) to the baseband and audio interface device BAI, it transmits it (or them) to the control device CD.
15 Then the control device CD transmits the data or command(s) to a control module CRM it comprises and which is arranged to access to the dedicated memory MM1 to determine in its coding table the coded value corresponding to the data or command(s) to transmit. Then the control module CRM transmits this coded value to the baseband device BBD in order it could be transmitted to the baseband and audio interface device BAI.

20 In the illustrated example the whole control device CD (control module CRM and dedicated memory MM1) is located inside the baseband device BBD, but this is not mandatory. Indeed, a part of the control device CD, and notably the dedicated memory MM1, may be located outside the baseband device BBD.

The coding table may be implemented as a software or firmware, but it could be also
25 a protocol stack running on the digital interface I.

The processing module PM of the baseband and audio interface device BAI comprises a dedicated memory MM2 storing a control table establishing a correspondence between the coding values of the coding table and symbols representing command words for controlling the operation of the modulator M and/or the gain controller GC and data words
30 for feeding the modulator M, and a control module CTM connected to the memory MM2, the digital interface I, to receive the transmit symbol bits coded with the coding table, and to the modulator M (and more precisely to the multiplexers MX_1 , MX_2 , MX_3 and MX_4 , and also to MX_0 when it is foreseen) and the gain controller GC.

When the control module CTM receives a coded value from the digital interface I,
35 i.e. transmit symbol bits coded with the coding table, it accesses to the dedicated memory MM2 to determine in its control table the word which corresponds to the received coded value. Then it transmits this word to the modulator M and/or to the gain controller GC.

In the illustrated example the control module CTM and the dedicated memory MM2 are located inside the baseband and audio interface device BAI, but this is not mandatory. Indeed, at least the dedicated memory MM2 may be located outside the baseband and audio interface device BAI.

5 The control table may be implemented as a software or firmware, but it could be also a protocol stack running on the digital interface I. The whole modulator including the protocol stack could be also implemented in firmware.

 The symbols of the second group may be used to define every type of command adapted to control the operation of the modulator M and/or the gain controller GC.

10 For instance a command word may be provided for assigning a chosen gain value to the gain controller GC, or for assigning a chosen working mode to the C0 filter F0 (multiplexers MX2_i) and/or the C1 filter F1 (multiplexers MX4_j) and/or the modulation part(s) MIa (multiplexers MX0 and MX1) and/or MIb (multiplexer MX3).

15 A command word may also be provided for assigning a chosen working mode to the C0 filter F0 (multiplexers MX2_i) and/or the C1 filter F1 (multiplexers MX4_j) and/or the modulation part(s) MIa (multiplexers MX0 and MX1) and/or MIb (multiplexer MX3) and a chosen gain value to the gain controller GC.

20 Here one means by “working mode” the above described initialization mode used to pre-load the filter(s) F0 and/or F1 with a chosen sequence of rotated valid symbols for an immediate up-ramping of the modulator M, or the above described reset mode used to force binary values of zero into all the delays of the modulator M for an immediate down-ramping of it, or else the transmission of valid data symbols out of the modulator’s alphabet.

 But other working modes may be envisaged.

25 When the modulator M or the gain controller GC receives a word from the control module CTM, it transmits it to the concerned element (multiplexer and/or serial to parallel converter and/or mapper and/or Finite State Machine and/or gain multiplier) in order it could carry out the corresponding action at the proper instant.

30 In case where the modulator M comprises a GMSK I/Q modulator M2₀ and M2₁ and a 8PSK I/Q modulator M1, the coding table and the control table are preferably of the type defined in the above cited document “DigRF, Baseband / RF digital interface specification : Logical, Electrical and timing characteristics”, Version1.12.

 More precisely, each coded value according to the digRF standard is a four-bit word comprising three most significant bits (MSB) and a low significant bit (LSB). The LSB is used to differentiate the GMSK I/Q modulator M2₀ and M2₁ from the 8PSK I/Q modulator M1.

35 The MSB are sent first.

 Moreover and still according to the digRF standard, the first group of symbols comprises ten symbols each dedicated to different data and the second group of symbols

comprises six symbols dedicated to different commands.

An example of coding table is given hereafter (the control table can be easily deduced from this coding table by inverting the input and the output):

<u>Output</u> (coded value)	<u>Output</u> (coded value)	<u>Input</u> (symbol)
Hexadecimal value	Binary value	Description
0x0	0b0000	GMSK symbol "0"
0x2	0b0010	GMSK symbol "1"
0x4	0b0100	Reset GMSK modulator (forced to zero) without gain change, symbol "R"
0x6	0b0110	Reset GMSK modulator (forced to zero) With gain change, symbol "RG"
0x8	0b1000	Pre-load GMSK modulator without gain change, symbol "P"
0xA	0b1010	Pre-load GMSK modulator With gain change, symbol "PG"
0xC	0b1100	Zero without gain change, symbol "Z"
0xE	0b1110	Zero with gain change, symbol "ZG"
0x1	0b0001	8PSK symbol "000"
0x3	0b0011	8PSK symbol "001"
0x5	0b0101	8PSK symbol "010"
0x7	0b0111	8PSK symbol "011"
0x9	0b1001	8PSK symbol "100"
0xB	0b1011	8PSK symbol "101"
0xD	0b1101	8PSK symbol "110"
0xF	0b1111	8PSK symbol "111"

5

It is important to notice that the stored coding table or control table does not need to comprise both hexadecimal values and binary values.

In this table the two first symbols are dedicated to the two different data words for the GMSK I/Q modulator $M2_0$ and $M2_1$, the six following symbols are initially dedicated to proprietary use and finally assigned to six modulator M (multiplexer configuration(s)) and/or gain controller GC (gain change) commands, and the last eight symbols are dedicated to the eight different data words for the 8PSK I/Q modulator $M1$.

Other formats of coded values may be envisaged.

According to the invention, it is now possible to use the proprietary bits i) to change gain(s) by means of digital multiplier(s) or analog scaling circuit(s), ii) to pre-load the FIR filters (FO and F1) for step-on of the regular I/Q pulse shaping filter, iii) to reset the FIR filter for step-off of the regular I/Q pulse shaping filter, iv) and to combine gain change(s) with pre-load, reset or forced to zero input.

The use of the command words (proprietary bits) is "meaningless" without an appropriate timing diagram defining the precise time at which each command word must be transmitted to the modulator M and/or the gain controller GC in order it could carries out the corresponding action at the proper instant.

A non limiting example of timing diagram, for the linearized GMSK I/Q modulator $M2$ and more precisely for its multiplexers $MX1$ and $MX3$ (in the upper part) and for its multiplexers $MX2$ and $MX4$ (in the lower part), is illustrated in figure 3.

Here the pre-loading (or initialization) takes place after the four leading guard bits referenced $G1$ to $G4$ which are followed by some specially defined other guard bits $G5$ to $G7$. These guard bits filled the guard interval which is inserted between two consecutive time slots filled with data bits.

More precisely, in this example, the guard period takes $G1, \dots, G7$ (guard bits) but the modulator $M2$ is switched on only after $G4$. So, during $G1, G2$ and $G3$ the multiplexers $MX1$ and $MX3$ are set to forced zero (second input on) while the multiplexers $MX2$ and $MX4$ are set to active (second input on). So, a smooth step-down from the previous GMSK burst is obtained. At $G4$, the multiplexers $MX1$ and $MX3$ are switched to GMSK2 (first input on) while the multiplexers $MX2$ and $MX4$ are set to pre-load (first input on) to enable the dummy sequence to be preloaded into the $C0$ or $C1$ filter. Thus, a fast amplitude transition occurs at the output and new data bits follow the dummy sequence and "real data" reach the output after 2.5 symbols.

In figure 3 tail bits $T0$ to $T2$ are followed by data bits (not shown and corresponding to a "normal" transmission), which are followed by other tail bits $T'0$ to $T'2$, and t/T_{bits} designates "normalized time scale".

In this example, the resetting part (forced zero) follows after the third trailing guard bit $G'3$, i.e. after the active part of the burst and after an additional transmission of three more specially defined guard bits ($G'0$ to $G'2$). The reset mode could be activated already during

G'0 but in practice it is preferable to introduce some time for the switch-off process.

The grey symbols in the upper part of figure 3 indicate that either one can be chosen.

In this example only actions on the modulator's multiplexers have been foreseen, but the resetting as well as the pre-loading may be combined with a gain change in the gain

5 controller GC.

The invention is not limited to the embodiments of control device, baseband device, baseband (and audio) interface device and wireless communication equipment described above, only as examples, but it encompasses all alternative embodiments which may be considered by one skilled in the art within the scope of the claims hereafter.

10 Thus, in the preceding description it has been described a modulator implemented as an integrated circuit, but the invention also applies to a modulator implemented as a pure look-up table where all values are pre-calculated and stored or else as pure firmware.

CLAIMS

1. Control device (CD) for controlling transmission of coded values onto a digital
5 interface (I) connecting a baseband device (BBD) and a baseband interface device (BAI),
comprising at least a modulator (M) feeding a gain controller (GC), of a wireless
communication equipment, said control device (CD) comprising a storing means (MM1) for
storing a coding table establishing a correspondence between symbols for said baseband
10 interface device (BAI) and coding values to transmit to said baseband interface device (BAI)
through said digital interface (I), characterized in that said coding table comprises a first group
of symbols comprising data words for feeding said modulator (M) and a second group of
symbols comprising command words for controlling the operation of said modulator (M)
and/or said gain controller (GC), and that it also comprises a control means (CRM) arranged,
when it receives a symbol from the baseband device (BBD), to determine in said storing means
15 (MM1) the coded value corresponding to this symbol in order it could be transmitted to said
baseband interface device (BAI) through said digital interface (I).

2. Control device according to claim 1, characterized in that at least one of the
symbols of said second group is a command word for assigning a chosen gain value to said
gain controller (GC).

20 3. Control device according to one of claims 1 and 2, characterized in that at least one
of the symbols of said second group is a command word for assigning a chosen working mode
to a filter means (F0,F1) and/or a modulation means (MIa,MIb) of said modulator (M).

4. Control device according to one of claims 1 to 3, characterized in that at least one
of the symbols of said second group is a command word for assigning a chosen working mode
25 to a filter means (F0,F1) and/or a modulation means (MIa,MIb) of said modulator (M) and a
chosen gain value to said gain controller (GC).

5. Control device according to one of claims 3 and 4, characterized in that said
working mode is chosen in a group comprising at least an initialization mode to pre-load said
filter means (F0,F1) with a chosen sequence of rotated valid symbols for an immediate up-
30 ramping of said modulator (M), a reset mode to force binary values of zero into said filter
means (F0,F1) of said modulator (M) for an immediate down-ramping of said modulator (M),
and a forced to zero mode to force at least one binary value of zero into said modulator (M).

6. Control device according to claim 5, characterized in that it is arranged to deliver a command word for assigning an initialization mode before transmission to said filter means (F0,F1) of a last guard bit filling a guard interval.

7. Control device according to one of claims 5 and 6, characterized in that it is arranged to deliver a command word for assigning a reset mode just after the transmission of an active part of a data burst to said filter means (F0,F1) and during a guard interval.

8. Control device according to one of claims 1 to 7, wherein said modulator (M) comprises a GMSK I/Q modulator (M2₀,M2₁) and a 8PSK I/Q modulator (M1), characterized in that each coded value is a four-bit word comprising three most significant bits and a low significant bit to differentiate said GMSK I/Q modulator and said 8PSK I/Q modulator.

9. Control device according to claim 8, characterized in that said first group comprises at least eight symbols and said second group comprises at least six symbols.

10. Baseband device (BBD) for a wireless communication equipment comprising a baseband interface device (BAI), adapted to be connected to said baseband device (BBD) through a digital interface (I), characterized in that it comprises a control device (CD) according to one of claims 1 to 9.

11. Baseband interface device (BAI) for a wireless communication equipment comprising a baseband device (BBD) according to claim 10, connected to it through a digital interface (I), said baseband interface device (BAI) comprising at least a modulator (M) and a gain controller (GC) fed by said modulator (M), characterized in that it comprises i) a storing means (MM2) adapted to store a control table establishing a correspondence between coding values, transmitted by said digital interface (I), and symbols representing command words for controlling its operation and data words for feeding said modulator (M), and ii) a control means (CTM) connected to said digital interface (I), modulator (M) and gain controller (GC), and arranged, when it receives a coding value from said digital interface (I), to determine in said storing means (MM2) the word corresponding to said received coding value in order to transmit it to said modulator (M) and/or said gain controller (GC).

12. Baseband interface device (BAI) according to claim 11, characterized in that it constitutes a baseband and audio interface device.

13. Baseband interface device (BAI) for a wireless communication equipment comprising a baseband device (BBD), connected to it through a digital interface (I), and a control device (CD) according to one of claims 1 to 9, said baseband interface device (BAI)

comprising at least a modulator (M) and a gain controller (GC) fed by said modulator (M), characterized in that it comprises i) a storing means (MM2) adapted to store a control table establishing a correspondence between coding values, transmitted by said digital interface (I), and symbols representing command words for controlling its operation and data words for feeding said modulator (M), and ii) a control means (CTM) connected to said digital interface (I), modulator (M) and gain controller (GC), and arranged, when it receives a coding value from said digital interface (I), to determine in said storing means (MM2) the word corresponding to said received coding value in order to transmit it to said modulator (M) and/or said gain controller (GC).

10 14. Baseband interface device (BAI) according to claim 13, characterized in that it constitutes a baseband and audio interface device.

15 15. Wireless communication equipment comprising a baseband device (BBD) and a digital interface (I), characterized in that it comprises a control device (CD) according to one of claims 1 to 9, connected to said baseband device (BBD), and a baseband interface device (BAI) according to one of claims 13 and 14, connected to said baseband device (BBD) through said digital interface (I).

20 16. Wireless communication equipment, characterized in that it comprises a baseband device (BBD) according to claim 10, a baseband interface device (BAI) according to one of claims 11 and 12, and a digital interface (I) connecting said baseband device (BBD) to said baseband interface device (BAI).

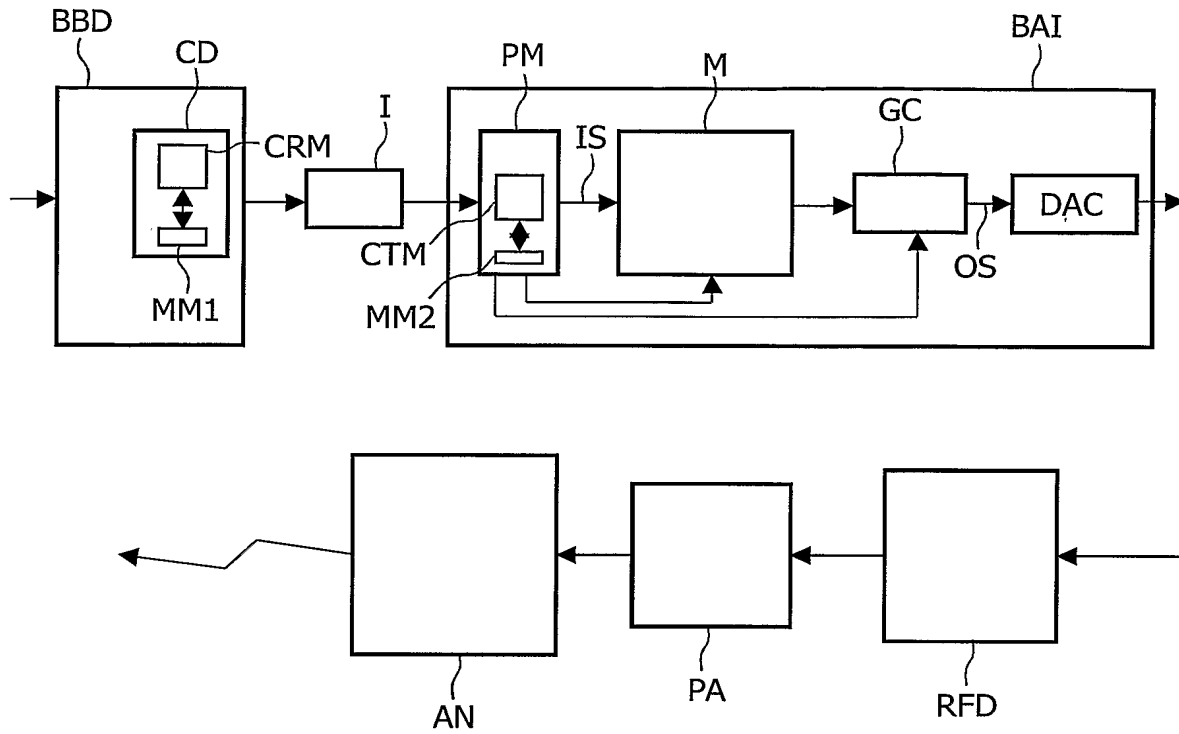


FIG. 1

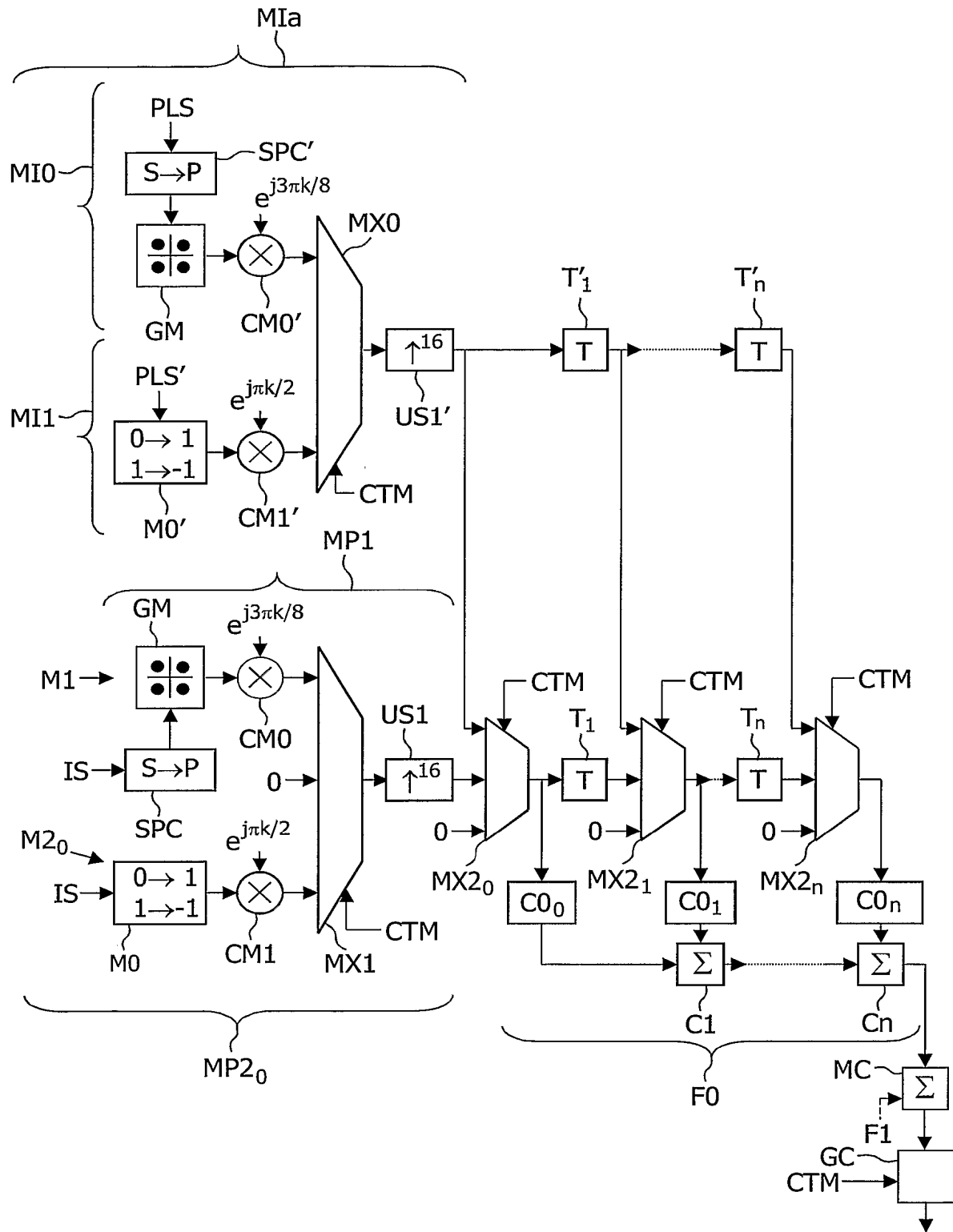


FIG. 2A

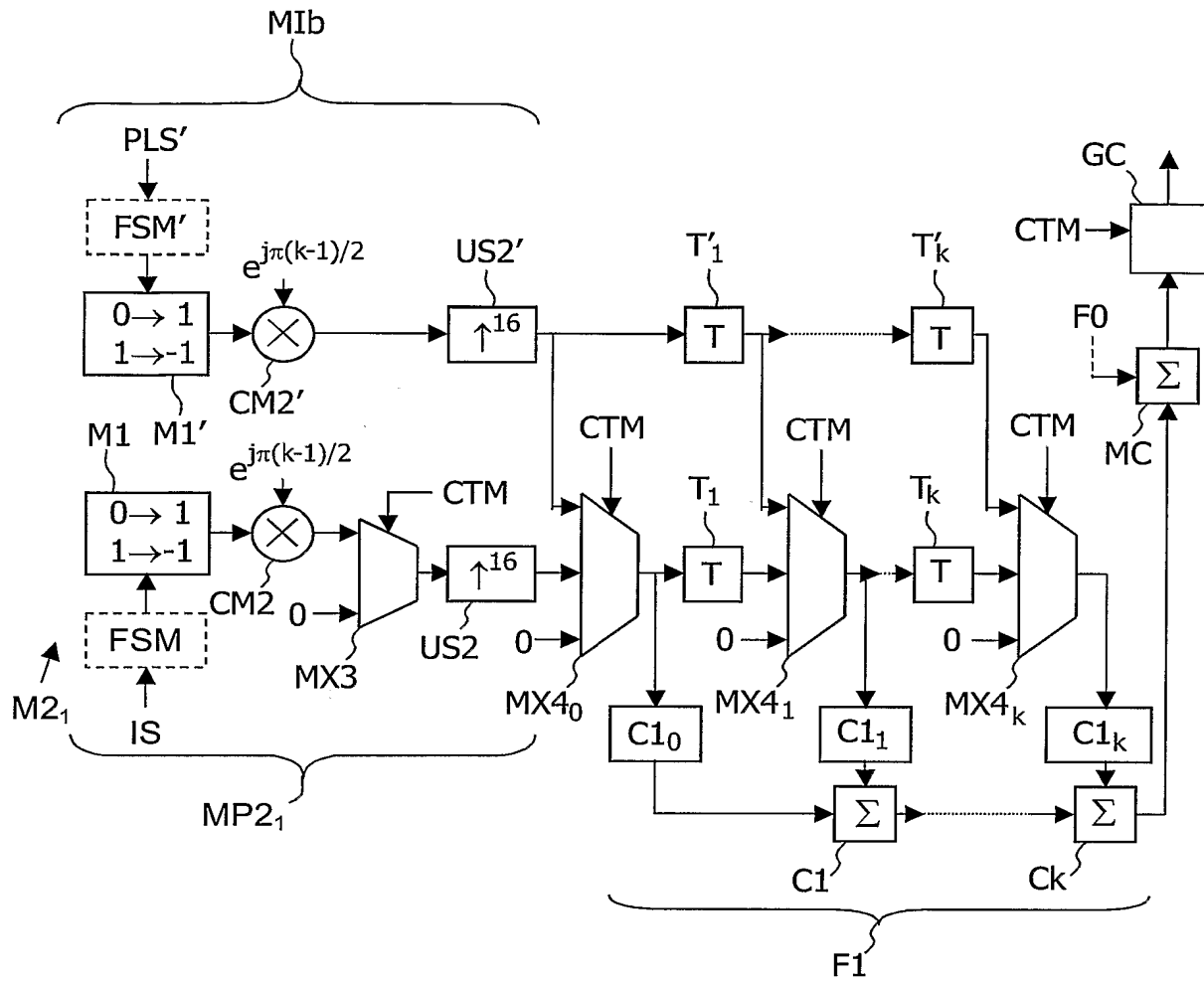


FIG. 2B

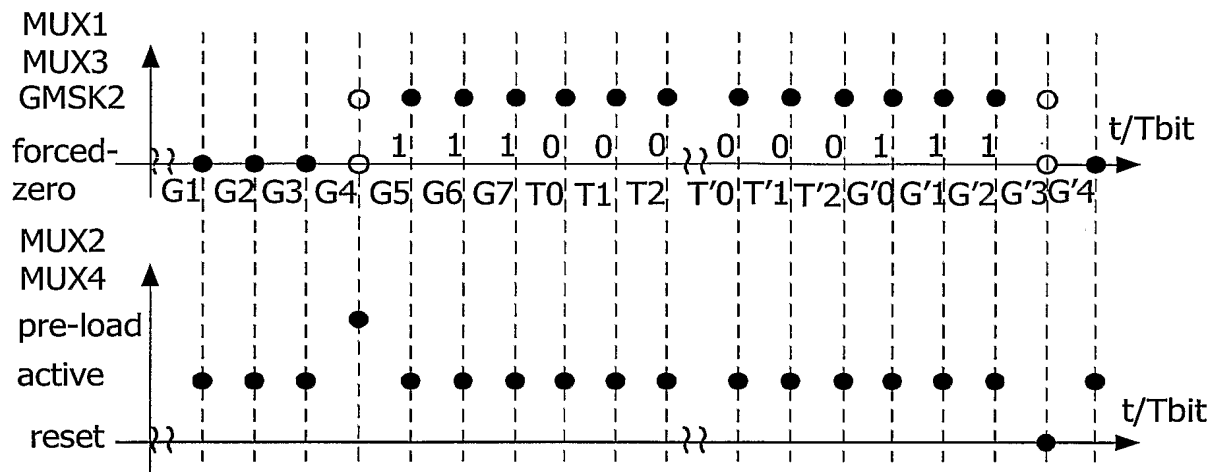


FIG. 3

INTERNATIONAL SEARCH REPORT

Intern I Application No
PCT, 2005/052312

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L27/00 H04B1/40 H04B1/20 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	<p>WO 2004/030228 A (INTERDIGITAL TECHNOLOGY CORPORATION) 8 April 2004 (2004-04-08)</p> <p>abstract</p> <p>paragraph '0005! - paragraph '0006!</p> <p>paragraph '0009! - paragraph '0013!</p> <p>paragraph '0021! - paragraph '0025!</p> <p>paragraph '0029!</p> <p>paragraph '0032!</p> <p>paragraph '0035!</p> <p style="text-align: center;">----- -/--</p>	<p>1-4, 10-16 5-9</p>

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

 Interr Application No
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